Assessment of cerebral oxygen supply-demand balance by near-infrared spectroscopy during induction of anesthesia in patients undergoing coronary artery bypass graft surgery

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Assessment of cerebral oxygen supply-demand balance by near-infrared spectroscopy during induction of anesthesia in patients undergoing coronary artery bypass graft surgery

Directed by Professor Soon Ho Nam

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<ABSTRACT>

Assessment of cerebral oxygen supply-demand balance by near-infrared spectroscopy during induction of anesthesia in patients undergoing coronary artery bypass graft surgery

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We evaluated the effect of midazolam on cerebral oxygen supply-demand balance by continuous monitoring of regional cerebral oxygen saturation (rSO_2) through near-infrared spectroscopy (NIRS). Near-infrared spectroscopy continuously measures regional cerebral oxygen saturation noninvasively and has been shown to detect even small changes in cerebral oxygen supply-demand balance.

60 patients scheduled for isolated off-pump coronary artery bypass graft surgery (OPCAB) between August 2006 and March 2007 were studied. Patients were randomly allocated into either midazolam (n = 30) or propofol (n = 30) group. Regional cerebral oxygen saturation was

recorded before induction while patients were breathing room air as baseline (T1), after pre-oxygenation with 100% oxygen (T2), after administration of either midazolam or propofol (T3), after completion of administration of sufentanil (T4) and after tracheal intubation (T5). The rSO_2 scores were similar between the groups throughout the study period. After pre-oxygenation at T2, rSO_2 scores were significantly increased compared to baseline scores at T1 in each group, and did not show any additional increase after administration of either midazolam or propofol and sufentanil in both groups. The rSO_2 scores at T5, 5 min after tracheal intubation showed no statistical significance compared to values of all other time points including baseline value in both groups.

We demonstrated midazolam preserves cerebral oxygen supply-demand balance to a similar degree to propofol which could be assessed by NIRS during induction of anaesthesia. NIRS is a simple monitoring device able to detect changes in cerebral oxygen supply-demand balance and further studies regarding identification of factors closely correlating with changes in rSO_2 scores are warranted.

Key words : midazolam, propofol, cerebral oxygen saturation, near-infrared spectroscopy.

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I. INTRODUCTION

During induction of general anesthesia, tracheal intubation can be far more stimulating than surgical incision requiring profound depth of anesthesia often at the expense of hypotension and bradycardia which may result in decreased cardiac output and myocardial ischemia.[1,2] Various induction agents and techniques have been introduced for patients with coronary artery occlusive disease. Among them, combination of either midazolam or propofol with sufentanil is being widely used with numerous studies reporting their hemodynamic stability.[3-5]

In addition to their safety profile in hemodynamic stability, propofol and sufentanil have been well studied in human subjects in terms of cerebral oxygen supply-demand balance with both agents decreasing cerebral blood flow and metabolism to a similar degree.[6-8] Although widely used, only the effect of

midazolam on cerebral blood flow has been studied in humans and evidence is lacking about its effect on cerebral metabolic rate.[9,10]

Near-infrared spectroscopy (NIRS) continuously measures regional cerebral oxygen saturation (rSO_2) noninvasively and has been shown to detect even small changes in cerebral oxygen supply-demand balance elicited by etomidate.[11-13] rSO_2 scores are also affected by many factors including changes in hemodynamic status, which commonly occurs during induction of general anesthesia.[14,15] By far, no comprehensive data exist regarding the influence of midazolam and hemodynamic changes on rSO_2 scores during the induction period.

We therefore evaluated the effect of midazolam on cerebral oxygen supply-demand balance by continuous monitoring of rSO_2 in a prospective, randomized and controlled trial with concomitant monitoring of hemodynamic variables including cardiac index (CI) and mixed venous oxygen saturation (SvO_2).

II. MATERIALS AND METHODS

1. MATERIALS

After institutional review board approval and with written informed consent, 60 patients scheduled for isolated off-pump coronary artery bypass graft surgery (OPCAB) between August 2006 and March 2007 were studied. A power analysis indicated that a sample size of 26 patients per group would be required to detect a difference of 8% in rSO_2 between the 2 groups with $\alpha = 0.05$ and $\beta = 0.8$. Patients were randomly allocated into either midazolam (n = 30) or propofol (n = 30) group by a computerized randomization table. Patients undergoing emergent surgery and those with pre-existing neurologic disease, lung parenchymal disease, NYHA functional class $\geqq$ 3, left ventricular ejection fraction < 40%, unstable angina and recent myocardial infarction within 1 month were excluded. Patients who had significant luminal narrowing of either carotid and/ or vertebral arteries on preoperative angiography were also excluded. All cardiovascular medications except diuretics were continued until the day of surgery.

2. METHODS

Upon arrival at the operating room, standard monitoring devices were applied and a radial artery catheter was inserted under local anesthesia for continuous blood pressure monitoring. Also, a pulmonary artery catheter (Swan-Ganz CCOmbo® CCO/SvO_2, Edwards Lifesciences LLC, USA) was inserted via the right internal jugular vein under local anesthesia for continuous measurements of CI and SvO_2. Bispectral index (A-2000TM, Aspect Medical Systems, Natwick, MA, USA) and rSO_2 (INVOS 5100™, Somanetics, Troy, MI, USA) were continuously monitored with both sensors applied to the forehead of the patients.

Hemodynamic variables, BIS and rSO_2 scores were recorded at the following time points; before induction while patients were breathing room air (T1, baseline), after pre-oxygenation with 100% oxygen for at least 3 min through tight-fitting anesthetic mask (T2), 3 min after administration of either midazolam 0.05 mg kg^{-1} or propofol 1 mg kg^{-1} according to randomization (T3), 3 min after completion of administration of sufentanil 1.5–2 μg kg^{-1} (T4) and 5 min after tracheal intubation (T5). The chosen doses of the drugs are conventionally used doses at our institution for induction of anesthesia in patients undergoing OPCAB which provide sufficient depth of anesthesia without recall.

Arterial blood gas analyses were performed at T1 and T5. Venous blood gas analysis was performed only at T1 for calibration of SvO_2. End-tidal carbon dioxide tension ($EtCO_2$) was monitored with side-stream capnography of the anesthesia machine (Primus, Drager, Lübeck, Germany) and also recorded at T2,

T3, T4 and T5. During T3 and T4, the patients' ventilation were manually assisted to obtain same level of $EtCO_2$ as T2 at a peak airway pressure < 1.9 kPa. Tracheal intubation was facilitated with rocuronium bromide 0.9 mg kg^{-1} which was administered either after the patients no longer obeyed to verbal command to open their eyes or BIS score was below 60. After tracheal intubation, the lungs were ventilated with a tidal volume of 8–10 mg kg^{-1}, at a rate of 8–12 breaths min^{-1} in 100% oxygen to obtain the same level of $EtCO_2$ as T2 without positive end-expiratory pressure during the study period.

During induction of anesthesia, 6-8 ml kg^{-1} of isotonic crystalloid solution was infused in all patients. Phenylephrine 100 μg was administered when the mean systemic arterial pressure (MAP) was decreased below 60 mmHg. Hemodynamic variables and rSO_2 scores before and after phenylephrine administration were also recorded.

Statistical analyses were performed using SPSS 12.0 (SPSS Inc., Chicago, IL, USA). Data were assessed for normal distribution of variance with Kolmogorov-Smirnov test. All data are expressed as number of patients or mean ± SD. Data between the groups were compared using Chi-square test, Fisher's exact test or independent t-test as appropriate. Changes between time points within the groups were compared using repeated-measures of ANOVA. A p value of less than 0.05 was considered as statistically significant.

III. RESULTS

Data from 60 patients were analyzed. Patients' characteristics were similar between the two groups (Table 1).

Table 1. Patients' characteristics.

	Midazolam (n = 30)	Propofol (n = 30)
Age (years)	65 ± 6	63 ± 9
Gender (M/F)	20 / 10	20 / 10
Body surface area (m^2)	1.7 ± 0.2	1.7 ± 0.2
Diabetes (n)	14	9
Hypertension (n)	18	20
Preoperative medication (n)		
Nitrate	2	7
β-Blockers	21	20
Calcium channel blockers	13	20
RAS antagonists	8	7
LVEF (%)	59 ± 12	63 ± 11

Data are expressed as mean ± SD or number of patients. No significant differences were observed between the groups.

RAS : renin-angiotensin system, LVEF : left ventricular ejection fraction.

Changes in BIS and rSO_2 scores are shown in Table 2.

Table 2. Changes in bispectral index, regional cerebral oxygen saturation, arterial oxygen saturation and end tidal carbon dioxide tension.

	Group	T1	T2	T3	T4	T5
BIS	Midazolam	95 ± 3*	94 ± 5*	71 ± 10*,†,‡	41 ± 6*,†,‡	41 ± 9†
	Propofol	93 ± 4	91 ± 6	58 ± 15†,‡	45 ± 7†,‡	43 ± 8†
rSO_2L (%)	Midazolam	65 ± 9	72 ± 9†	74 ± 9†	72 ± 9†	70 ± 9
	Propofol	66 ± 7	74 ± 8†	74 ± 8†	73 ± 9†	70 ± 9
rSO_2R (%)	Midazolam	64 ± 10	71 ± 9†	73 ± 9†	71 ± 9†	68 ± 9
	Propofol	66 ± 7	74 ± 8†	74 ± 8†	73 ± 10†	70 ± 10
SaO_2 (%)	Midazolam	96 ± 2	100 ± 1†	100 ± 0†	99 ± 0†	100 ± 0†
	Propofol	96 ± 3	100 ± 1†	100 ± 0†	100 ± 0†	100 ± 0†
$EtCO_2$ (kPa)	Midazolam		4.6 ± 0.5	4.6 ± 0.6	4.5 ± 0.5	4.5 ± 0.4
	Propofol		4.7 ± 0.3	4.6 ± 0.4	4.5 ± 0.4	4.5 ± 0.4

Data are expressed as mean ± SD, $^{*}p < 0.05$ compared to propofol group, $^{\dagger}p < 0.05$ vs T1, $^{\ddagger}p < 0.05$ compared to value of the previous time point.

BIS : bispectral index, rSO_2 : regional cerebral oxygen saturation, SaO_2 : arterial oxygen saturation, $EtCO_2$: end tidal carbon dioxide tension, L : left, R : right, T1: while patients were breathing room air, T2 : 3 min after breathing 100% oxygen through tight-fitting anesthetic mask, T3 : 5 min after administration of either midazolam 0.05 mg kg^{-1} or propofol mg kg^{-1}, T4 : 3 min after completion of administration of sufentanil 1.5–2 mg kg^{-1}, T5 : 5 min after tracheal intubation.

BIS scores were significantly higher at T1, T2, T3 and lower at T4 in the midazolam group. At T3, after administration of either midazolam or propofol, 27 patients in the midazolam group and all patients in the propofol group did not respond to verbal command to open their eyes, despite BIS scores being over 60 in 25 and 14 patients in each group, respectively. BIS scores in all patients fell below 60 after administration of sufentanil at T4 and none of the patient had recall afterwards.

The rSO_2 scores were similar between the groups throughout the study period. After pre-oxygenation at T2, rSO_2 scores were significantly increased compared to baseline scores at T1 in each group, and did not show any additional increase after administration of either midazolam or propofol and sufentanil in both groups. The rSO_2 scores at T5, 5 min after tracheal intubation showed no statistical significance compared to values of all other time points including baseline value in both groups.

Arterial oxygen saturations measured by pulse oximetry were similar between the groups and were significantly increased after pre-oxygenation and remained constant thereafter throughout the study period in each group.

Arterial carbon dioxide tension and pH at T1 and T5 and $EtCO_2$ from T2 to T5 were similar between the groups with no significant differences between each time points within group.

Arterial oxygen tensions were 11.9 ± 2.2 kPa, 52.1 ± 9.9 kPa in the midazolam group and 11.5 ± 1.5 kPa, 54.9 ± 9.3 kPa in the propofol group at T1 and T5, respectively with both groups showing significant increase compared to baseline values at T1 of each group. Hematocrit concentrations were 37 ± 4%, 33 ± 4% in the midazolam group and 38 ± 4%, 35 ± 4% in the propofol group at T1 and T5, respectively with both groups showing significant decrease compared to baseline values at T1 of each group without any significant difference between the groups (Table 3).

Table 3. Changes in arterial oxygen tension and hematocrit

	Group	Room air	After tracheal intubation
Arterial oxygen tentsion (kPa)	Midazolam	11.9 ± 2.2	52.1 ± 9.9*
	Propofol	11.5 ± 1.5	54.9 ± 9.3*
Hematocrit (%)	Midazolam	37 ± 4	33 ± 4*
	Propofol	38 ± 4	35 ± 4*

Data are expressed as mean ± SD, *$p < 0.05$ vs room air

Changes in hemodynamic variables are shown in Table 4.

Table 4. Changes in hemodynamic variables.

	Group	T1	T2	T3	T4	T5
CI (litre min^{-1} m^{-2})	Midazolam	3.0 ± 0.6	3.1 ± 0.6	3.2 ± 0.6	3.2 ± 0.6	3.1 ± 0.6
	Propofol	3.0 ± 0.5	3.0 ± 0.4	3.0 ± 0.5	3.1 ± 0.4	3.2 ± 0.6
SvO_2 (%)	Midazolam	74 ± 3	82 ± 5*	85 ± 6*	82 ± 6*	82 ± 9*
	Propofol	76 ± 3	82 ± 5*	84 ± 5*	83 ± 6*	82 ± 6*
MAP (mmHg)	Midazolam	97 ± 14	99 ± 14	84 ± 15*,†	70 ± 11*,†	75 ± 16*
	Propofol	101 ± 20	103 ± 12	84 ± 12*,†	70 ± 9*,†	79 ± 11*
CVP (mmHg)	Midazolam	7 ± 3	6 ± 3	7 ± 3	7 ± 3	7 ± 3
	Propofol	7 ± 3	7 ± 3	8 ± 2	7 ± 2	7 ± 2

Data are expressed as mean ± SD, *$p < 0.05$ vs T1, †$p < 0.05$ compared to value of the previous time point.

T1 : while patients were breathing room air, T2 : 3 min after breathing 100% oxygen through tight-fitting anesthetic mask, T3 : 5 min after administration of either midazolam 0.05 mg/kg or propofol mg kg^{-1}, T4 : 3 min after completion of administration of sufentanil 1.5–2 mg kg^{-1}, T5 : 5 min after tracheal intubation, CI :cardiac index, SvO_2 : mixed venous oxygen saturation, MAP : mean systemic arterial pressure, CVP : central venous pressure.

CI and central venous pressure (CVP) were similar between the groups throughout the study period with no significant differences between each time points within group. SvO_2 and MAP were also similar between the groups throughout the study period. SvO_2 was increased in both groups at T2, T3, T4 and T5 compared to baseline values of each group. MAP was decreased in both groups at T3, T4 and T5 compared to baseline values of each group.

Phenylephrine bolus to maintain MAP at predefined level was administered to 12 and 11 patients in the midazolam and propofol group, respectively. All phenylephrine boluses were required during or after sufentanil administration. In the 23 patients, MAP was decreased to a range of 51–60 mmHg and significantly increased after phenylephrine administration with no significant changes in rSO_2 scores (Table 5).

Table 5. Changes in regional cerebral oxygen saturation scores and hemodynamic variables of the 23 patients who required phenylephrine administration.

	After hypontics			Before phenylephrine			After phenylephrine		
rSO_2L (%)	76	±	7	75	±	7	75	±	8
rSO_2R (%)	76	±	7	75	±	7	75	±	8
CI (litre min^{-1} m^{-2})	3.0	±	0.6	3.0	±	0.6	3.0	±	0.5
SvO_2 (%)	83	±	4	83	±	4	82	±	6
MAP (mmHg)	79	±	11	56	±	4*	74	±	10†
CVP (mmHg)	7	±	2	7	±	2	7	±	3

Data are expressed as mean ± SD, *$p < 0.05$ vs after hypnotics, †$p < 0.05$ vs

before phenylephrine.

rSO_2 : regional cerebral oxygen saturation, L : left, R : right, CI : cardiac index, SvO_2 : mixed venous oxygen saturation, MAP : mean systemic arterial pressure, CVP : central venous pressure.

None of the patients developed ECG changes indicative of ischemia during the study period or newly developed segmental regional wall motion abnormalities on transoesophageal echocardiography immediately thereafter.

IV. DISCUSSION

In this study, we demonstrated that midazolam preserves cerebral blood flow-metabolism coupling to a similar degree to propofol as assessed by NIRS. We could also observe that pre-oxygenation alone causes significant increase in rSO_2 scores and that neither midazolam nor propofol with sufentanil exerted additional increase on rSO_2 scores. Transient decrease in MAP after sufentanil administration to a range of 51–60 mmHg and subsequent increase with phenylephrine bolus was not associated with significant changes in rSO_2 scores.

NIRS noninvasively provides continuous, real-time rSO_2 and is being increasingly used to detect disturbances in cerebral oxygen supply-demand balance, especially in carotid endarterectomy and cardiac surgeries.[16,17] It also has been validated to detect even small changes in cerebral oxygen supply-demand balance elicited by administration of etomidate during propofol anesthesia.[13] However, to evaluate subtle changes in cerebral oxygen supply-demand balance with NIRS after administration of a certain drug, other factors affecting rSO_2 scores such as hemodynamic variables and hematocrit concentration should also be assessed and taken into consideration.[18-21] In addition, to avoid confounding effects of other anesthetic drugs, which are known to affect cerebral blood flow and or metabolic rate, the drug which is to be evaluated should be administered exclusively. In accordance, we have assessed the effects of midazolam on cerebral oxygen supply-demand balance by NIRS, with strict control of arterial pH by maintaining $EtCO_2$ constant at its preinduction value and concomitant monitoring of beat to beat hemodynamic changes including CI and SvO_2. The reason we concomitantly monitored SvO_2

was that, in case of constant cardiac output, any changes in SvO_2 may reflect significant changes in the oxygen extraction ratio of major organs including the brain, which implies changes in oxygen supply-demand balance.[22,23] We also administered midazolam exclusively before any other anesthetics and used propofol as active control. Propofol already has been well studied in terms of preserving cerebral oxygen supply-demand balance in human subjects by reducing both cerebral blood flow and metabolic rate to a similar degree.[7,24]

As our results indicate, arterial oxygen saturation, $EtCO_2$ and SvO_2 remained constant after pre-oxygenation within each group and were also similar between the groups at all time points. CI, MAP and CVP were similar between the groups throughout the study period. CI and CVP also remained constant in both groups compared to baseline values of each group throughout the study period. Although MAP was significantly decreased in both groups after administration of either midazolam or propofol compared to values of T1 and T2 of each group, it was well within the range of cerebral autoregulation. Midazolam, propofol and sufentanil are all known to preserve cerebral autoregulation.[7,8,10] The independence of MAP and rSO_2 scores, shown when MAP was further decreased to below 60 mmHg after administration of sufentanil and subsequently increased with phenylephrine in the 23 patients, indicate preserved cerebral autoregulation and that MAP is an unlikely contributing confounder to the observed rSO_2 scores.[25] Under the above mentioned conditions, the observed rSO_2 scores assessed by NIRS indicate that midazolam preserves cerebral oxygen supply-demand balance to a similar degree as propofol.

Interestingly, after administrating 100% oxygen, reversing signs of

neurological deficit following cross clamping of carotid artery have been reported probably due to increase of the mitochondrial oxygen tension above the critical level to restart oxidative phosphorylation in ischemic cerebral neurones.[26] In accordance, there is a report of suggesting that breathing oxygen 100% by the awake patients or induction of general anesthesia using a high fraction of inspired oxygen, while monitoring the cerebral oxygen supply–demand by cerebral oximetry can enhance the cerebral oxygen supply–demand balance and may decrease the need for inserting a shunt in patients who are liable to develop neurological deficits during carotid endarterectomy.[27]

We could also observe similar results with high inspired oxygen fraction and rSO_2 scores in all 60 patients supporting their suggestion. However, we could not observe additional significant increase in rSO_2 scores after induction of general anesthesia. This observation may be in part attributed to decrease in hematocrit concentration as a result of hemodilution induced by administration of 6 – 8 ml kg^{-1} of isotonic crystalloid solution during the induction period.[28]

The limitations of our study are as follows. The rSO_2 probes in this study were attached in the forehead measuring rSO_2 of the watershed territory corresponding to the junction of anterior and middle cerebral artery.[11] Thus, our results may not accurately reflect changes of global cerebral oxygen supply-demand balance, although we have excluded patients with significant luminal narrowing of the carotid and vertebral arteries. After administration of either midazolam or propofol, there were significant differences of BIS scores between both groups. For this reason, although the chosen doses of the drugs

are conventionally used doses at our institution for induction of anesthesia in patients undergoing OPCAB, we cannot exclude the possibility of differences in potency between doses of the drugs.

V. CONCLUSION

In conclusion, in addition to its safety profile with regard to hemodynamic stability, midazolam preserves cerebral oxygen supply-demand balance to a similar degree to propofol which could be assessed by NIRS during induction of anesthesia. The balance was maintained even when MAP was decreased to 51 mmHg, with intact cerebral autoregulation observed as independence of rSO_2 scores and changes in MAP. NIRS is a simple monitoring device able to detect changes in cerebral oxygen supply-demand balance and further studies regarding identification of factors closely correlating with changes in rSO_2 scores are warranted.

REFERENCES

1. Vuyk J, Lim T, Engbers FH, Burm AG, Vletter AA, Bovill JG. The pharmacodynamic interaction of propofol and alfentanil during lower abdominal surgery in women. Anesthesiology 1995; 83: 8-22.

2. Zbinden AM, Maggiorini M, Petersen-Felix S, Lauber R, Thomson DA, Minder CE. Anesthetic depth defined using multiple noxious stimuli during isoflurane/oxygen anesthesia. I. Motor reactions. Anesthesiology 1994; 80: 253-60.

3. Lehmann A, Zeitler C, Thaler E, Isgro F, Boldt J. Comparison of two different anesthesia regimens in patients undergoing aortocoronary bypass grafting surgery: sufentanil-midazolam versus remifentanil-propofol. J Cardiothorac Vasc Anesth 2000; 14: 416-20.

4. Kleinschmidt S, Grundmann U, Janneck U, Kreienmeyer J, Kulosa R, Larsen R. Total intravenous anaesthesia using propofol, gamma-hydroxybutyrate or midazolam in combination with sufentanil for patients undergoing coronary artery bypass surgery. Eur J Anaesthesiol 1997; 14: 590-9.

5. van der Maaten JM, Epema AH, Huet RC, Hennis PJ. The effect of midazolam at two plasma concentrations of hemodynamics and sufentanil requirement in coronary artery surgery. J Cardiothorac Vasc Anesth 1996; 10: 356-63.

6. Oshima T, Karasawa F, Satoh T. Effects of propofol on cerebral blood flow and the metabolic rate of oxygen in humans. Acta Anaesthesiol Scand 2002; 46: 831-5.

7. Vandesteene A, Trempont V, Engelman E, Deloof T, Focroul M, Schoutens A,

et al. Effect of propofol on cerebral blood flow and metabolism in man. Anaesthesia 1988; 43 Suppl: 42-3.

8. Stephan H, Groger P, Weyland A, Hoeft A, Sonntag H. The effect of sufentanil on cerebral blood flow, cerebral metabolism and the CO_2 reactivity of the cerebral vessels in man. Anaesthesist 1991; 40: 153-60.

9. Veselis RA, Reinsel RA, Beattie BJ, Mawlawi OR, Feshchenko VA, DiResta GR, et al. Midazolam changes cerebral blood flow in discrete brain regions: an H2(15)O positron emission tomography study. Anesthesiology 1997; 87: 1106-17.

10. Forster A, Juge O, Morel D. Effects of midazolam on cerebral blood flow in human volunteers. Anesthesiology 1982; 56: 453-5.

11. Taillefer MC, Denault AY. Cerebral near-infrared spectroscopy in adult heart surgery: systematic review of its clinical efficacy. Can J Anaesth 2005; 52: 79-87.

12. Owen-Reece H, Smith M, Elwell CE, Goldstone JC. Near infrared spectroscopy. Br J Anaesth 1999; 82: 418-26.

13. Lovell AT, Owen-Reece H, Elwell CE, Smith M, Goldstone JC. Continuous measurement of cerebral oxygenation by near infrared spectroscopy during induction of anesthesia. Anesth Analg 1999; 88: 554-8.

14. Hung YC, Huang CJ, Kuok CH, Chen CC, Hsu YW. The effect of hemodynamic changes induced by propofol induction on cerebral oxygenation in young and elderly patients. J Clin Anesth 2005; 17: 353-7.

15. Madsen PL, Secher NH. Near-infrared oximetry of the brain. Prog Neurobiol 1999; 58: 541-60.

16. Cuadra SA, Zwerling JS, Feuerman M, Gasparis AP, Hines GL. Cerebral oximetry monitoring during carotid endarterectomy: effect of carotid clamping and shunting. Vasc Endovascular Surg 2003; 37: 407-13.

17. Yao FS, Tseng CC, Ho CY, Levin SK, Illner P. Cerebral oxygen desaturation is associated with early postoperative neuropsychological dysfunction in patients undergoing cardiac surgery. J Cardiothorac Vasc Anesth 2004; 18: 552-8.

18. Yoshitani K, Kawaguchi M, Iwata M, Sasaoka N, Inoue S, Kurumatani N, et al. Comparison of changes in jugular venous bulb oxygen saturation and cerebral oxygen saturation during variations of haemoglobin concentration under propofol and sevoflurane anaesthesia. Br J Anaesth 2005; 94: 341-6.

19. Akca O, Liem E, Suleman MI, Doufas AG, Galandiuk S, Sessler DI. Effect of intra-operative end-tidal carbon dioxide partial pressure on tissue oxygenation. Anaesthesia 2003; 58: 536-42.

20. Torella F, Haynes SL, McCollum CN. Cerebral and peripheral oxygen saturation during red cell transfusion. J Surg Res 2003; 110: 217-21.

21. Torella F, Cowley RD, Thorniley MS, McCollum CN. Regional tissue oxygenation during hemorrhage: can near infrared spectroscopy be used to monitor blood loss? Shock 2002; 18: 440-4.

22. Cariou A, Monchi M, Dhainaut JF. Continuous cardiac output and mixed venous oxygen saturation monitoring. J Crit Care 1998; 13: 198-213.

23. Reinhart K, Kuhn HJ, Hartog C, Bredle DL. Continuous central venous and pulmonary artery oxygen saturation monitoring in the critically ill. Intensive Care Med 2004; 30: 1572-8.

24. Stephan H, Sonntag H, Schenk HD, Kohlhausen S. Effect of Disoprivan (propofol) on the circulation and oxygen consumption of the brain and CO_2 reactivity of brain vessels in the human. Anaesthesist 1987; 36: 60-5.

25. Jalowiecki P, Pioro A, Dziurdzik P, Karawczyk L, Karpel E, Dyaczynska-Herman A. Regional cerebral oxygenation monitoring in children undergoing elective scoliosis surgery with controlled urapidil induced hypotension Med Sci Monit 1998; 4: 987-92.

26. Stoneham MD, Martin T. Increased oxygen administration during awake carotid surgery can reverse neurological deficit following carotid cross-clamping. Br J Anaesth 2005; 94: 582-5.

27. Baraka AS, Nawfal M, El-Khatib M, Haroun-Bizri S. Regional cerebral oximetry after oxygen administration. Br J Anaesth 2005; 95: 720.

28. Han SH, Ham BM, Oh YS, Bahk JH, Ro YJ, Do SH, et al. The effect of acute normovolemic hemodilution on cerebral oxygenation. Int J Clin Pract 2004; 58: 903-6.

< ABSTRACT(IN KOREAN)>

관상 동맥 우회로술을 시행받는 환자의 마취유도시 근적외선 뇌산소포화도 측정기(near-infrared spectroscopy)을 통한 뇌산소 전달 및 소모 균형의 평가

<지도교수 남 순 호>

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김 민 수

본 연구는 근적외선 뇌산소포화도 측정기(Near-infrared spectroscopy, NIRS)를 이용하여 뇌산소포화도를 지속적으로 측정함으로써 midazolam의 뇌산소 전달 및 소모 균형(cerebral oxygen supply-demand balance)에 대한 효과를 알아보고자 하였다. 근적외선 뇌산소포화도 측정기는 비침습적으로 뇌산소포화도를 지속적으로 측정하는 장치로 뇌산소 전달 및 소모 균형의 작은 변화도 잘 반영하는 것으로 알려져 있다.

2006년 8월부터 2007년 3월까지 체외순환없는 관상 동맥 우회로술(off-pump coronary artery bypass graft surgery, OPCAB)을 시행하는 60명의 환자를 대상으로 하고 무작위로 마취유도시 midazolam을 투여 받는 군(n = 30명)과 propofol을

투여 받는 군(n = 30명)으로 나누어 연구를 진행하였다. 뇌산소포화도는 기준값으로 대기 중에서 호흡하는 동안 측정하고 (T1), 100% 산소 마스크를 통해 탈질소화를 시행한 후(T2), midazolam 또는 propofol을 정주한 후(T3), sufentanil을 정주한 후(T4), 그리고 기관내삽관을 시행한 5분 후(T5) 각각 기록하였다. 각 시점에서 두 군의 뇌산소포화도의 값은 차이를 보이지 않았다. 각 군에서 100% 산소로 탈질소화 후(T2) 뇌산소포화도값이 기준값(T1)에 비해 의미있게 증가한 후 midazolam 또는 propofol 그리고 sufentanil을 투여 후에 추가적인 증가는 없었다. 기관삽관 후 5분 후의 값은 각 군에서 기준값을 포함한 어느 시점에 값과 비교하여도 통계학적인 의미를 가지지 않았다.

본 연구를 통해서 midazolam이 propofol과 비슷한 정도로 뇌산소 전달 및 소모 균형을 유지하는 데 효과가 있음을 마취 유도하는 동안 뇌산소포화도 측정을 통해 확인할 수 있었다. 뇌산소포화도 측정기는 뇌산소 전달 및 소모 균형의 변화를 평가하는 간단한 장치로 앞으로 뇌산소포화도에 영향을 미치는 인자에 대한 연구가 더 필요할 것으로 생각된다.

핵심되는 말 : 미다졸람, 프로포폴, 뇌산소포화도, 뇌산소포화도 측정기